

# The Exercise Test in Electrocardiography

## Detection of Coronary Artery Disease

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CORONARY ATHEROSCLEROSIS may be present to a significant degree in a person who has no history suggestive of the condition and in whom it is not disclosed by physical examination or by electrocardiograms made at rest. A simple and reliable test for detecting latent coronary artery disease in such a person would be of great value. Several reports in recent years have described the use for this purpose of the electrocardiogram made after exercise.<sup>4</sup> The two-step exercise test developed by Master<sup>2</sup> seemed to the authors the most logical test because it is well standardized for age, weight and sex, is simple for the subject to carry out, and does not involve unusual activity or occasion anxiety. Master has recommended that the test be used in the routine examination of persons over the age of 35 years, those undergoing excessive stress, athletes, military recruits, pilots and industrial employees.<sup>5, 6</sup>

This presentation describes the authors' experience with Master's test in the examination of 595 employees of a large airline, of whom 283 were males over 40 years old and 243 were younger males. Whereas most published reports of exercise tests<sup>1, 3, 7, 8</sup> are concerned with patients in whom the diagnosis of heart disease had been made or was being considered, the study here reported was made in connection with routine physical examinations of persons who were considered healthy. The authors were particularly interested in evaluating the test as a means of detecting latent coronary artery disease in such persons.

### METHOD

A twelve-lead electrocardiogram was made on each subject at rest. Three electrocardiograms were made with the three standard leads and the fourth unipolar chest lead, one of them immediately after exercise, another at two minutes, and the third at six minutes. All electrocardiograms were made with the subject recumbent, in a quiet, relaxed atmosphere and at least an hour after eating.

The exercise in the standard two-step test consists in walking back and forth over two steps nine inches high for a specified number of trips in one and one-half minutes, the number of trips depending on age, weight and sex. It has been reported that in cases in

• Master has proposed a test for detection of latent coronary artery disease by means of electrocardiograms made after standard exercises consisting of walking back and forth over two steps. This test was used in routine examinations of airline employees, with the special purpose of evaluating the test for use on apparently normal persons.

Of 526 males tested, 283 were under 40 years of age and 243 were aged 40 years or more. Coronary artery disease was indicated in 16 males in whom there was no other evidence of the disease, five of whom had hypertension. No electrocardiographic evidence of coronary artery disease was obtained for three males in whom the disease was diagnosed or was strongly suspected. The test gave negative results for 16 males whose electrocardiograms made at rest were compatible with coronary artery disease. The percentage of positive results in men under 40 years of age was 4.3; in men over 40, 0.6.

Of a control group of 69 women under the age of 35 years, in none of whom coronary artery disease was detected by other means, six had positive response to the test.

It is concluded that Master's criterion for the most common positive finding, a depression in the ST segment of over 0.5 mm., allows too many false positive findings and that a figure of 1.0 mm. to 1.5 mm. would be a better index. A negative finding apparently does not exclude the possibility of coronary artery disease or of coronary occlusion. The usual 12-lead electrocardiogram made at rest appeared to be of greater value in detection of latent coronary artery disease in apparently normal persons.

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which positive findings are not obtained with this test they may be obtained with the double test, in which twice the number of trips are made in three minutes. To minimize the possibility of false negative results, the double test was used exclusively in the study here reported. A Sanborn Viso-Cardiette was used throughout the entire study.

Master's criteria<sup>4</sup> were used in interpreting the electrocardiograms:

1. A depression of the ST segment in any lead of over 0.5 mm. as compared with the PR interval of the same cycle, the level of the string just following the QRS complex being compared with that immediately preceding the complex. (To avoid erroneous interpretation of ST segment levels, only those series of beats having an essentially horizontal base line were considered.)

2. Changes in T wave direction in any lead, except the third standard lead.

3. Development of arrhythmias or large abnormal Q waves.

4. Changes from normal to abnormal conduction.

Five hundred and twenty-six males were studied, 283 under 40 years of age and 243 aged 40 years or more. Of the males, 157 were flight employees and 369 were not. Because of the rarity of coronary atherosclerosis in healthy young females, 69 females under the age of 35 years were tested as a control series.

#### RESULTS AND REPORTS OF CASES

Electrocardiograms made after the exercise test gave positive results in 11 males for whom there was no evidence of coronary artery disease on clinical examination or in electrocardiograms made at rest:

Age	Occupation	Electrocardiogram Following Exercise*
32	Flight Engineer	ST depression 1.0 mm. in V <sub>4</sub> , rate 85.
34	Pilot	ST depression 0.75 to 1.0 mm. in standard leads II and III, rate 110.
32	Pilot	ST depression 1.5 mm. in V <sub>4</sub> , rate 78.
30	Pilot	ST depression 0.75 to 1.0 mm. in standard leads II and III, rate 90 (Figure 1).
30	Pilot	ST depression 0.75 to 1.0 mm. in V <sub>4</sub> , rate 90.
35	Stockroom clerk	ST depression 0.75 in standard lead II, rate 85.
35	Laborer	ST depression 0.75 to 1.0 mm. in standard lead III, rate 62.
36	Laborer	ST depression 1.5 mm. in V <sub>4</sub> , rate 80.
35	Junior executive	ST depression 0.75 mm. in V <sub>4</sub> , rate 92.
37	Office Employee	ST depression 1.0 mm. in standard lead II, 0.75 mm. in V <sub>4</sub> , rate 90.
42	Mechanic	ST depression 1.0 mm. in V <sub>4</sub> , rate 114.

Positive results were noted in electrocardiograms made immediately after exercise in five males in whom no abnormality was evidenced by electrocardiograms made at rest but who had hypertension:

1. A 34-year-old flight engineer had no history of cardiovascular disease. Blood pressure was 150 to 160 mm. of mercury on systole, 90 to 96 mm. on diastole. He was moderately obese and had prematurely gray hair. No abnormal-

\*All abnormalities described occurred in tracing taken immediately after exercise with return to normal limits within six minutes.

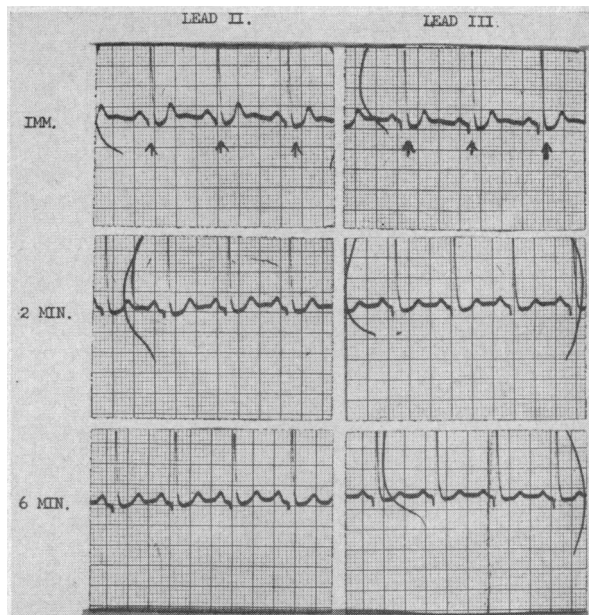


Figure 1

ity was noted on examination of the heart and the heart appeared of normal size in an x-ray of the chest. In the electrocardiogram taken after the exercise test there was an ST depression in V<sub>4</sub> of 0.75 to 1.0 mm. at a rate of 124.

2. A 61-year-old mechanic had hypertension without symptoms. Blood pressure was 170 mm. of mercury on systole, 100 mm. on diastole. No abnormality was noted on examination of the heart and the heart appeared of normal size in an x-ray film. In the electrocardiogram taken after the exercise test there was an ST depression of 1.0 mm. in V<sub>4</sub> immediately after exercise at a rate of 100.

3. A 41-year old ground employee had no history of cardiovascular disease and no evidence of such disease on physical examination, except for blood pressure of 160 mm. of mercury on systole and 100 mm. on diastole. In the electrocardiogram taken after the exercise test there was an ST depression in V<sub>4</sub> of 1.0 mm. at a rate of 60.

4. A 54-year-old ground employee had no history of cardiovascular disease and no evidence of it in examination of the heart except for blood pressure of 180 mm. of mercury on systole and 100 mm. on diastole. The heart appeared of normal size in an x-ray film. In the electrocardiogram taken after the exercise test there was a depression of ST of 1.0 mm. in lead II and of 0.5 to 0.75 mm. in lead III and V<sub>4</sub>, at a rate of 86.

5. A 40-year-old office employee, prematurely aged in appearance, had had hypertension for about seven years (blood pressure 180 mm. of mercury on systole, 100 mm. on diastole). The arterioles in the ocular fundi showed Group II changes (Keith-Wagener-Barker). There was a blowing murmur of grade 2 to 3 on systole, in the fourth interspace near the left sternal border, which had not been observed in previous examinations. The heart appeared of normal size in an x-ray film. In the electrocardiogram after the exercise test there was depression of ST in lead II of 0.75 mm. at a rate of 90.

Electrocardiograms made at rest and after exercise gave no evidence of abnormality in three males in whom coronary artery disease was diagnosed or was suspected on clinical evidence:

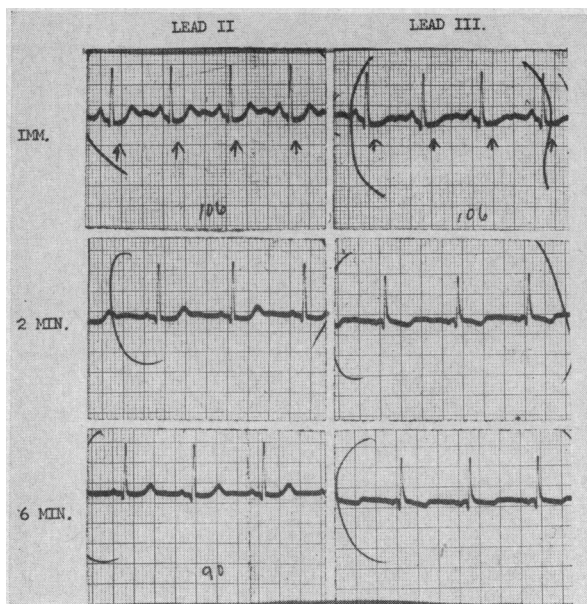


Figure 2

1. A 53-year-old ground worker had no history of heart disease, and physical examination and electrocardiograms disclosed no abnormality. Six months later he was suddenly seized with severe substernal pain which radiated to the left arm, the jaw and the upper back. He was immediately hospitalized but died four hours after the onset of pain. At autopsy advanced coronary atherosclerosis was found, and also a recent coronary occlusion which was considered to be the cause of death.

2. A 55-year-old male who was examined for employment was 66 inches tall and weighed 270 pounds. Blood pressure was 180 mm. of mercury on systole and 90 mm. on diastole. Glycosuria (3 plus) was noted. Electrocardiographic findings were within normal limits and no other abnormalities were observed. The subject refused further studies to determine the significance of the glycosuria; it can only be suspected that he had diabetes mellitus. (Strong suspicion of coronary artery disease in this case was based on extreme obesity, hypertension and glycosuria.)

3. A 36-year-old white male had no history of heart disease, and no such abnormality was observed on physical examination or in electrocardiograms. He remained apparently in good health for 19 months until severe crushing substernal pain developed with radiation down the left arm. After the pain had persisted for several hours he was hospitalized. Serial electrocardiograms made during four weeks of hospitalization were compatible with the diagnosis of anterior myocardial infarction.

For 16 males who had no clinical evidence of rheumatic or other non-coronary heart disease, and for whom electrocardiograms made after exercise gave no sign of abnormality, there were findings compatible with a diagnosis of coronary artery disease in electrocardiograms made at rest. Of these subjects, five had right or left bundle branch block. The others had abnormalities in the T, Q, or R waves or defective intraventricular conduction. These 16 were 3.04 per cent of the 526 males examined.

Of the 69 females under the age of 35 years who were examined, none had any history of cardiovascular disease or any indication of such disease observed in physical examination or in electrocardiograms made at rest, but six had positive response to the test in electrocardiograms made after exercise. In these six there was no evidence of neurocirculatory asthenia, unusual emotional reaction to the test, anemia, or other extracardiac factors which might have caused false positive reaction. These six were 8.7 per cent of all the females examined. Abnormalities observed electrocardiographically were as follows:

Age	Occupation	Electrocardiogram Made After Exercise*
24	Secretary	ST depression 0.75 to 1.0 mm. in V4, rate 98.
32	Stewardess	ST depression 0.75 to 1.0 mm. in standard lead II, rate 112.
22	Stewardess	ST depression 0.75 mm. in standard lead II and V4, rate 90.
22	Stewardess	ST depression 0.75 to 1.0 mm. in standard lead II and V4, rate 114.
27	Secretary	ST depression 0.75 mm. in standard lead III, rate 110.
26	Secretary	ST depression 0.75 to 1.0 mm. in standard leads II and III, rate 106 (Figure 2).

#### DISCUSSION

Of the men in this study who had no evidence of heart disease observed by other tests, the ten under the age of 40 years with positive response to the exercise test were 4.3 per cent of the 232 in their age group, and the man over 40 years of age was 0.6 per cent of the 169 in his age group. The possibility of undue anxiety at the time of the test can be reasonably excluded in the case of these 11 men, and such factors as thyroid or digitalis medication, abnormal tachycardia following exercise, or eating shortly before the test, which have been reported<sup>5</sup> as causing false positive results, were absent in all cases.

Master states<sup>5</sup> that positive findings in this test may be the only objective indication of coronary disease. The authors hesitate to conclude, however, that the 11 men had coronary artery disease, as the proportion of men under the age of 40 years with positive response to the test is relatively high as compared with the older group, a finding incompatible with the expectation for these ages.

In the case of the five men with hypertension, the electrocardiogram made immediately after exercise was the only one indicating possible association of hypertension with coronary artery disease. An adequate follow-up period will be necessary for evaluation of these findings, which have made the authors

\*All abnormalities described occurred in tracing taken immediately after exercise and all returned to resting level within six minutes.

alert to the possibility of coronary artery disease in these persons but do not seem to justify a conclusive diagnosis. If false positive findings can be obtained in normal persons, it is reasonable to assume that such findings may also be obtained in those who have hypertension.

Of special interest by contrast is the finding of positive response in electrocardiograms made at rest in 16 persons who had negative response after exercise—apparently a detection rate approximately four times as great as that for the exercise test. This proportion is of course somewhat conjectural, since in either group there is a possibility of false positive response. This possibility is further confirmed by the findings in healthy young women. Indeed, the electrocardiograms which were interpreted as positive in this series would have been considered negative by the stricter criteria of other investigators than Master.<sup>8</sup> Depression of the ST segment, which was the most frequent change in the electrocardiograms, was nowhere greater than 1.5 mm. From the frequency with which depression as great as 1 mm. occurs in apparently normal persons it seems likely that this result should be considered within normal range.

The possibility of false negative results, emphasized by the frequency of negative results in men over 40 years of age, must be considered even in the case of the three men in whom coronary artery disease was diagnosed or strongly suspected. Adequate follow-up of all cases with negative findings will be necessary to clarify this aspect of the problem.

As most of those examined had apparently normal hearts, the authors cannot evaluate the test as an aid in the differential diagnosis of pain in the chest or in the study of patients with overt cardiac disease or coronary insufficiency. In evaluating the test as an aid in the detection of unsuspected coronary artery disease at the time of routine periodic examination, it must be kept in mind that coronary artery disease can be present without causing symptoms of coronary insufficiency. It is probable that many persons who have atherosclerosis of the coronary artery—and who might at any moment have coronary occlusion—have “adequate” coronary flow after exercise, insofar as adequacy can be determined from clinical history and examination. In

such circumstances the result of the test might be negative even though the person tested was a candidate for myocardial infarction.

#### CONCLUSIONS

On the basis of the findings in the study here reported, the following conclusions seem justified:

1. In tests on an average group of persons, a significant number of electrocardiograms made after the two-step exercise have a depression in the ST segment of over 0.5 mm. Therefore a standard of 1.0 to 1.5 mm. for this reading would be a better index of coronary artery disease and would be less likely to lead to false positive interpretation.

2. A negative finding in a double two-step exercise test does not exclude the possibility of latent coronary artery disease or of coronary occlusion.

3. The usual 12-lead electrocardiogram made at rest appears to be of more value than the electrocardiogram made after exercise in the detection of latent coronary artery disease in apparently normal persons.

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